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NAEB TECHNICAL REPORT ON THE IMPACT OF AIRBORNE TELEVISION TRANSMISSION ON LAND-BASED UHF TELEVISION ASSIGNMENT PLANS.

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OPERATIONAL EFFECTS OF AIRBORNE EDUCATIONAL TELEVISION ON ULTRAHIGH FREQUENCY (UHF) TELEVISION ASSIGNMENTS ON LAND WERE INVESTIGATED. SPECIFICALLY, THE EFFORT RELATED TO EXPANSION PLANS OF THE MIDWEST PROGRAM ON AIRBORNE TELEVISION INSTRUCTION (MPATI). PREVIOUS STUDIES BY THE NATIONAL ASSOCIATION OF EDUCATIONAL BROADCASTERS (NAEB) LED TO THE DEVELOPMENT OF COMPUTER PROGRAMS WHICH WERE USED IN PRESCRIBING A UHF ASSIGNMENT TABLE. THE SPEED OF THE COMPUTER AND ACCESSIBILITY OF DATA IN THE COMPUTER PROGRAM MADE IT PRACTICAL TO DETERMINE THE IMPACT OF THE PROPOSED MPATI EXPANSION IN TWO CONTEXTS--(1) BY USING NEW STANDARDS WHICH MPATI HAD RECOMMENDED, AND (2) BY USING STANDARDS DEVELOPED BY NAEB ENGINEERS. THE COMPUTER WAS PROGRAMED TO PRINT OUT THE LOCATION AND CHANNEL NUMBER OF ASSIGNMENTS WHICH WOULD HAVE TO BE DELETED IF MPATI PROPAGATION CURVES WERE ADOPTED, AND THOSE WHICH WOULD HAVE TO BE DELETED IF NAEB STANDARDS WERE ADOPTED. THE STUDY INDICATED THAT NO FEWER THAN 60 CHANNELS WOULD BE AFFECTED BY THE MPATI PROPOSAL. FOR THE NAEB PLAN, 83 CHANNELS WOULD BE INVOLVED. IF NEW STANDARDS PROPOSED BY THE MPATI WERE USED, AS MANY AS 46 PROPOSED ASSIGNMENTS WOULD NEED TO BE DELETED. (JC)

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NAEB TECHNICAL REPORT ON THE IMPACT OF AIRBORNE TELEVISION TRANSMISSION ON LAND-BASED UHF TELEVISION ASSIGNMENT PLANS

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Washington, D. C.

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FOREWORD

The information in this report has been used in a more detailed report* concerned with airborne television transmission for educational use. Although the data here provide a sound basis for proceeding cautiously on the authorization of a six-channel airborne television system, other considerations that need attention must also be weighed at the same time.

Accordingly, the NAEB has used the information from this study and report in a more complete publication dealing with other educational and further technical aspects of airborne television operation.

* NAEB, Report of the NAEB Study on the Proposed Expansion of the Midwest Program on Airborne Television Instruction, March, 1964

INTRODUCTION

A petition for rule-making was filed by the Midwest Program on Airborne Television Instruction (MPATI) on January 15, 1963, looking toward (1) the regular use of UHF channels for airborne educational television in the six-state Midwest area of Illinois, Indiana, Kentucky, Michigan, Ohio and Wisconsin; (2) the adoption of special or new engineering rules and criteria governing such airborne educational television use; and (3) the regular allocation of six specific UHF television channels for airborne educational television use in the six-state Midwest area. Comments were invited on or before January 3, 1964, and Reply Comments on or before February 3, 1964.[1/]

On October 3, 1959, Purdue University, Lafayette, Indiana, filed applications for "experimental" stations to use airborne television to provide educational programing to elementary schools, secondary schools, colleges and universities located within a raduis of approximately 200 miles of Montpelier, Indiana. The major purpose of the experimental grant was to determine whether it is economically and technically feasible to make better use of the television spectrum by "splitting" television channels, thereby

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1/ These two dates were extended to April 3, 1964 and June 3, 1964 respectively.

permitting two different signals to be transmitted on a standard television broadcast channel.

As justification for the experiment, Purdue pointed to the increased enrollment expected in schools and colleges and the necessity of providing education of the highest quality to a greater number of students at the lowest possible price. Purdue maintained that a system using multi-channel airborne television held definite promise of achieving this goal, especially with a technical system to make more efficient use of the channels.

On December 22, 1959, the Commission, responding to the Purdue request, granted permission for the construction of experimental airborne television stations to operate on Channels 72 and 76. Other airborne facilities were authorized for Channels 75 and 78, and four ground-to-air facilities were authorized to use UHF channels.

The Midwest Program on Airborne Television Instruction (MPATI) started its first full academic year of the airborne program in September, 1961. From a modified DC-6 aircraft flying figure-eight patterns 23,000 feet above Montpelier, Indiana, program materials were radiated simultaneously on Channels 72 and 76 to classrooms generally within a 200-mile radius.

The television signals are broadcast by means of a 24-foot long retractable transmitting antenna, lowered straight down from

the underside of the aircraft in flight, and stabilized to maintain a vertical position. One plane is maintained on standby status while the other flies during the program day. Each has a six-man crew, three flight crew members, and three television technicians.

To solve problems associated with the reception of an adequate and stable direct-to-school signal from the airborne transmitter in larger metropolitan areas such as Cleveland, Chicago, and Detroit the MPATI has used supplementary translator facilities in these cities.[2/] In order to facilitate the experiment, the FCC assigned temporary use of Channels 79 and 83 in Detroit and Chicago and 81 and 83 in Cleveland.

The following annotation from the MPATI petition for rule-making filed with the Federal Communications Commission in January, 1963, describes another type of rebroadcast situation.[3/]

> "Most schools were receiving the UHF signals direct from the airborne transmitters over equipment especially installed for the purpose. Several hundred other schools in

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2/ Translators operate on UHF frequencies covered by Channels 70 to 83, and they are not normally used to provide a receivable signal within the main coverage of a station, but are used to provide a signal beyond the range of the main station, which they pick up with special receiving equipment and re-radiate.

3/ "Petition for Rule-Making Submitted by Midwest Program on Airborne Television Instruction, Inc." Dr. John E. Ivey, Jr., President, pp. 1-73; Attorney for Petitioner: Percy H. Russell of Kirkland, Ellis Hodson, Chaffetz and Masters, Washington 6, D.C., January 15, 1963.

> the greater Chicago area received about half the courses over their VHF receivers via rebroadcasts from WTTW--an ETV station in Chicago. Similarly, in Columbus, Ohio, some schools that wished to use one of the courses at a time different from that scheduled from the aircraft did so via rebroadcasts from the educational station WOSU-TV."

In the engineering exhibit accompanying the petition for proposed rule-making[4/] it is proposed that the experimental operation engaged in to date be converted to a regularly licensed operation, and that a regular airborne service be established which would provide for four broadcast channels in addition to those now in use, and six ground-to-air channels. Specifically, it was proposed that six channels near the upper end of the UHF television band operate with 100 kilowatts visual ERP and 10 kilowatts aural, ERP. In its petition, the MPATI has indicated that its engineering study justifying this use is based upon new propagation curves for signal coverage which ignore certain of the FCC channel assignment "taboos" and mileage separation requirements. As a consequence, the MPATI is also asking for a change in the FCC Rules regarding interference criteria.

4/ "Engineering Exhibit-Petition for Rule-Making to Authorize the Use of Airborne Television Transmitters," T. A. Wright - A. Earl Cullum, Jr., Dallas, Texas, January 11, 1963.

TECHNICAL FACTORS AFFECTING THE IMPACT OF AIRBORNE TRANSMISSION ON LAND-BASED TELEVISION STATIONS

(At several points in this section of the report, material is quoted from central sources. To assist in understanding the excerpt, it has been quoted in context, making some of the citations somewhat longer than usual. In several instances, the NAEB has underlined the sentences which are especially pertinent. In cases where tables or page numbers appear, these of course, refer to the original document which is cited.)

In its Notice proposal for regularization and expansion of the MPATI service, the FCC listed a number of questions dealing primarily with technical concerns about the impact of an airborne television service using six channels, on ground-based channel assignments, both in the area currently covered by the MPATI and in a nationwide projection of the service.

Most of these questions dealt with the determination of reliable standards and curves which would permit calculation of the impact of airborne transmission on ground-based stations. The basis for development of these standards is included in this section of the report.

The technical standards of the Federal Communications Commission for television, and their evolution to include airborne considerations, are fundamental to this matter. In evaluating the question of standards, factors relating to signal propagation interference considerations, taboos, field study data, translators, and UHF channel utilization must be considered. Because the

knowledge gained in the past 20 years concerning television generally will be helpful as a guide in these considerations, this background is detailed in this part of the report.

Technical Background for Propagation Determinations

From Radio Technical Planning Board (RTPB) considerations beginning in 1943 through Joint Technical Advisory Committee (JTAC) efforts commencing in 1948 to study the possibilities of using UHF and a review of the entire allocations problem,5/ to 1956, television grew in various cycles. In September of that year, with VHF frequencies rapidly becoming exhausted, the FCC called a meeting of industry representatives for the purpose of expediting research and development of UHF technical operation. Subsequently the Television Allocations Study Organization (TASO) was formed with the objectives set forth as follows:

> "The objectives of this organization shall be to develop full, detailed and reliable technical information, and engineering principles based thereon concerning present and potential VHF and UHF television service."

In 1959 TASO issued its comprehensive report.6/

5/ "Radio Spectrum Conservation," JTAC IRE-RTMA, pp. 1-221; McGraw-Hill, 1952.

6/ "Engineering Aspects of Television Allocations," TASO Report to the FCC, pp. 1-731; March, 1959. See also Proceedings of the IRE, TASO issue, Vol. 48; June, 1960.

In January, 1960, a new Notice of Proposed Rule-Making, (identified as Docket No. 13340), was issued by the Federal Communications Commission. The Commission therein invited comment on its proposal to:

a) Consider applications for waivers of minimum television station separation in exceptional, individual cases meeting certain criteria; and

b) Adopt revised rules and standards governing calculations of the service areas of television broadcast stations.

In a further Report and Order dated August 3, 1961, in this docket case and its relationship to proposals to short space certain VHF assignments, the Commission indicated that additional VHF channels could not be secured and that it was clear that if a fully competitive nationwide television system were to be created, UHF frequencies must be utilized.1/

In a Notice of Proposed Rule-Making also issued August 3, 1961, the Commission established a new Docket No. 14229 consideration in the Matter of Fostering Expanded Use of UHF Television Channels. Matters such as deintermixture, short-spaced VHF assignments, relaxation of technical requirements, remote control, and ratio of visual to aural power were set forth for comment relating to expanded use of UHF channels.

1/ "Interim Policy on VHF Television Channel Assignments and Amendment of Part 3 of the Rules Concerning Television Engineering Standards, Docket No. 13340 and RM-35 -- RM-248," Pike and Fisher, 21RR1696, Paragraph 2.

On January 19, 1963, a Memorandum Opinion and Order in Docket No. 14229 and the corollary matters of deintermixture in eight cities, contained the following statement:

> "In determining service losses if existing VHF stations were required to shift to UHF channels, we were guided by the field strength charts in our present rules. These are not intended to be used to estimate the service area of an individual station, but they do provide a convenient administrative tool for comparing station coverage on a statistical probability basis. The theoretical service area of the existing VHF station was considered to extend to its Grade B contour selected from the appropriate F(50, 50) field strength chart in our present rules on the basis of the actual effective radiated power and antenna height used. The estimate of the probably UHF service area is more difficult to make. The only 'official' field strength charts available are those contained in our present rules, which are the same curves as are used to estimate the Channel 2-6 coverage. There is almost unanimous agreement that these curves are too optimistic. The T.A.S.O. group developed a set of 'critical distances' which purported to give the practical service range of UHF television stations derived empirically from field observations of picture quality. In 1956 the Commission issued a set of UHF field strength charts, commonly referred to as 'Appendix A.' There was no general agreement as to the acceptability of these curves and they were withdrawn. However, field strength measurement data obtained by T.A.S.O. closely approximated the Appendix A curves. In the absence of generally accepted curves, we used the Appendix A curves as a starting point and assumed that the UHF station would employ an effective radiated power of 500 kilowatts from an antenna about 750 feet above average terrain. Such a station was assumed to provide acceptable service for 50% of the locations 90% of the time out to a distance of approximately 40 miles, which is the highest 'critical distance' from T.A.S.O., substantially below the estimate derived from the F(50, 50)

curves of our present rules and slightly below the distance of the Grade B contour shown by the Appendix A curves."8/

Appendix "A" references above are generally to the document issued October 22, 1956, by the FCC Technical Research Division.9/ This report consisting of 8 pages, 5 tables, and 15 figures was concerned with service curves, interference curves, and techniques for service calculation. Some of the material in this report which establishes one of the limits to be observed in an assessment of such allocation factors with respect to the air-borne service is quoted below.

With regard to interference:

"It was shown that, for distances greater than above 20 miles beyond the horizon, the over-all long-term time fading was substantially independent of distance and antenna height. The tropospheric fading trends versus frequency are shown in Figure 1. The top plot shows the ratio of 1% to the 10% fields, and the bottom plot shows the ratio of 10% to the 50% fields. The long-term fading distribution is approximately log-normal."

Concerning Service Contours:

"It should be emphasized that these curves of Figures 6, 7, and 8, represent an average of many

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8/ "In the Matter of Fostering Expanded Use of UHF Television Channels in the Matters of Deintermixture of Madison, Wisconsin, etc., Docket No. 14229 and Docket Nos. 14239; 14246," Pike and Fisher 21RR1725, Paragraph 6 (partial).

9/ "Propagation Data and Service Calculation Procedures Used for the Rescinded Appendix "A" of the Report and Order (Docket No. 11532) Released June 26, 1956," Fine and Taff, T.R.R. Report No. 2.4.16, Federal Communications Commission.

measurements made in all kinds of terrain. They may be termed propagation curves of typical terrain. However, the service fields over smooth terrain are expected to be greater than these curves indicate and, conversely, the service fields over rough terrain are expected to be lower than indicated by the curves. Further, the departures from the average curves will increase with frequency so that the variation at UHF will be substantially greater than at VHF."

The following considerations under the category of Techniques for Service Calculation are pertinent:

"In estimating the available rural service in the presence of noise only, the required local field intensities of the Third Notice of Further Proposed Rule Making were modified on the basis of additional data supplied by the Industry and others in response to the Commission's request for such information in Docket No. 11433, Notice of Proposed Rule Making, issued June 24, 1955, concerning the proposal to increase the maximum power for UHF stations. A good installation is assumed for describing these outer limits of acceptable rural service. As described in the previous Appendix "A", the assumed local field intensities required to overcome rural noise are 35, 44, and 53 dbu for Channels 2-6, 7-13, and 14-83, respectively. For Channels 2-6 a receiver noise figure of 6 db was assumed, for Channels 7-13 a receiver noise figure of 8 db and antenna gain improvement of 3 db were used; for the UHF a receiver noise figure of 10 db and a transmission line loss of 3 db were assumed.

"It cannot be emphasized too strongly that the propagation curves represent the average of many measurements and that under actual conditions the true signal strength may vary from these values appreciably, especially at UHF. It should therefore be recognized that proper measurements should always be more accurate than the average curves. The techniques for computing service may be used with such measurements also, if a sufficient number are available."

A document issued by Westinghouse Electric Corporation and the Glenn L. Martin Company of Baltimore and Middle River, Maryland, respectively summarized the Stratovision tests conducted on television Channel 6, 250 Mc/s, 750 Mc/s and 3300 Mc/s from December 5, 1947, to February 17, 1949.[10] This series of tests followed original airborne experiments using a smaller plane conducted from December 9, 1945, to August 30, 1946. These earlier tests were conducted on 1 Mc/s, 107.5 Mc/s and 514 Mc/s. The 1947-1949 measurements program was conducted generally with the aircraft operating at 20,000 to 30,000 feet. Measured values of field strength at a receiving location in Baltimore, Maryland, for the various frequencies over radial distances are shown on pages 300 to 331 of that report. A general range for the UHF frequencies in use today was predicted as about 200 miles for operation at 26,000 feet.[11]

Propagation factors from high antennas are considered and the following excerpts are of interest:

"3. Nulls Due to Ground Reflections.

> "Figures 5-49 all show the typical interference patterns which are obtained due to alternate reinforcement and cancellation of the direct and ground-reflected waves when the transmitting and receiving antennas are high enough to allow many complete wave-lengths difference in the path lengths.

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[10] "Results of Stratovision B-29 Flight Tests," Westinghouse Electric Corporation and the Glenn L. Martin Company, Baltimore, Md., 1949.

[11] Ibid, page 484.

"For example, Figure 48 shows that at 5.14 m.c., with a 30,000 foot transmitting antenna, a 30 foot receiving antenna, and 1 KW effective radiated power, a field intensity is not as strong and at three of these points, the field intensity is less than .1 MV/meter. This would be a marked disadvantage of a high transmitting antenna if it were not for the fact that the position of these nulls can be changed by changing the receiving antenna height. For example, Figure 47 shows that the null at 132 miles can be completely eliminated by reducing the receiving antenna height to 15 feet, resulting in a field intensity of 1.6 MV/meter.

"4. Co-Channel Interference.

"Figures 1 through 4 also show how the interference ranges compare for a 500 foot and a 30,000 foot transmitting antenna. At 475 megacycles, about 1.5 millivolts/meter is required for a 30 db signal-to-noise ratio, and with 25 KW effective radiated power, this is 49.5 db above microvolt/meter/KW. An interfering signal is supposed to be down 40 db to avoid co-channel interference, making the interference signal 9.5 db above 1 microvolt/meter/KW. From Figure 3 it can be seen that the service range for the 500 foot antenna is 39 miles and the interference range is 195 miles, while the service range for the 30,000 foot antenna is 220 miles and the interference range is 397 miles. Thus the service range of the 30,000 foot antenna is about 5-½ times that of the 500 foot antenna, while the interference range is only doubled."

Picture ghosting problems are discussed in part as follows:

"It can be seen from Figures 67-69 that the ghost amplitude gets much stronger if the reflecting object is close to either the transmitting or receiving antenna. From Figure 73 it can be seen that a reflecting object must be much further away to produce a ghost if the angle between it and the other antenna is small. From this it follows that the maximum ghost amplitude will be much less at small angles. This effect is increased by the fact shown

in Figure 70, that a reflecting object at a given distance cannot produce as strong at small angles as it can at large angles. A directional antenna, which will not respond to ghost signals, except at small angles, can reduce very substantially the maximum amplitude of ghost signals. This effect has been calculated for a few typical antennas and is plotted on Figure 74. It should be realized that to get this gain, the directional antenna must be the receiving antenna, and it must be the transmitting antenna if the reflecting object is near it. More ghost signals exist due to the reflections from near the receiving antenna, because the transmitting antenna location can be carefully chosen, but, when ghosts are caused by reflecting objects near the transmitting antenna, it is practically impossible to eliminate them, since a directional transmitting antenna cannot be used for this purpose. When the transmitting antenna is at 30,000 feet, no such ghosts will exist, because there will be no reflecting objects close enough to the transmitting antenna to cause trouble."

Problems of an airborne transmitter are discussed in Chapter II, pages 411-414. Since many items of importance are discussed therein, the material in Sections 1 and 2 is quoted in its entirely. Sections 3 and 4 discuss the transmitting antenna and airborne equipment respectively.

"1. General.

"If a television transmitter is placed in an airplane, a big advantage is immediately gained because of the increased antenna height. At the same time, however, many new problems are introduced which must be considered before it can be determined whether the idea is practical.

"2. Effect of Aircraft Motion.

"An airplane cannot remain motionless with respect to the ground unless its air speed is equal and opposite to the wind velocity. While high wind velocities are

quite common at high altitudes, they are not nearly consistent enough that they may be depended upon, and it is necessary to specify a circle of some fixed diameter within which the plane will stay, rather than specifying a fixed location as can be done for a ground station.

"This immediately reduces the maximum range of the station by a distance equal to the radius of this circle, since at some point in its circle the plane will be that much further from a distant point, and usable signal during part of the cycle would not be much help.

"The interference range of the station is at the same time increased by the radius of the circle, since at another point on its circle the plane will be that much closer to a distant point.

"Both of these effects are serious enough that they must be considered in determining the service area and interference area of an airborne station, but the size of the plane's circle can be kept small enough compared to the maximum range of the transmitter that the statements previously made concerning the increased service range and increased ratio of service area to interference area for a high antenna are not markedly changed.

"Figure 74 shows the minimum size circle which a plane flying 145 m.p.h. can stay inside of for various wind velocities and angles of bank. Two sets of curves are included. Those in which the diameter of the circle increases with increasing wind velocity are for a course in which the plane continually circles in one direction, flying in a straight line against the wind after each circle for the time required to return the distance the wind carries it during the circle. As the wind velocity increases, the wind carries the plane further as it circles, thus increasing the maximum dimension of the course. For high wind velocites, the plane can stay inside a smaller circle by flying continuously into the wind, banking first to the right and then to the left just enough to keep the average forward velocity

of the plane equal to the wind velocity. This course gets smaller as the wind velocity increases, reaching a point when the wind velocity equals the plane velocity. The second set of curves applies to this type of course.

"If the velocity of the plane is increased, the size of the circle is increased for the same angle of bank. Since small angles of bank are desirable for a practical transmitting antenna, a slow plane is helpful in maintaining a small diameter circle.

"The size of circle given by Fig. 74 is that which is required theoretically. In practice, a larger circle will be needed to take care of variations from the theoretical course. How much it is necessary to add for this factor will depend on how well informed the pilot is of his position. With low wind velocities, a pilot could keep pretty close to the theoretical course with aid of a standard radio beacon with a fan marker, by following the beacon until his indicator showed him to be over the fan marker, and then making a full 360 degree circle, straightening out twice during the circle, once when heading into the wind to compensate for his drift during the circle, and once at the 180 degree point to assure his getting back on the beacon before reaching the fan marker, which would give him time before the next circle to make any necessary corrections. With higher wind velocities, the error in such a system would become more serious, so that it would be necessary to either provide a better means of maintaining the course or to allow for substantial deviations from the theoretical course.

"It is feasible to design an automatic pilot system which would cause a plane to follow fairly accurately either of the theoretical courses which have been described provided the proper wind velocity and direction were fed into it. It also seems entirely possible that a practical system could be devised which would determine drift from radio markers of some sort and use this information to feed corrections into such an automatic pilot to keep the plane close to the theoretical course authomatically and indefinitely.

"Even though a receiving location may receive sufficient signal for a usable picture during the entire circle of the airplane, the signal may vary enough during the cycle to be objectionable. Figures 5-49 show that, if no nulls are encountered, the signal strength can vary by two or three to one for each 10 mile motion of the plane in the VHF television band, while in the UHF band, the ratio can become as high as five to one. For receivers which are not located too far away from the plane, this ratio can be minimized by adjusting the height of the receiving antenna so that the operating point is in the flat-topped region between two nulls, preferably the two most distant nulls. For receivers very close to the plane where such an arrangement would result in an impractically low antenna, an antenna with some vertical directivity can be used, pointed up to discriminate against the ground-reflected wave. For receivers located near the maximum range of the transmitter, no practical antenna will prevent the variation. The variation occurs quite slowly, since it takes the plane several minutes to make a circle and much longer variations can occur without being objectionable than would be the case with rapid variations. Experience has shown that at Channel 6 (82-88 m.c.) the effect is bad enough to make the picture unusable. In the UHF band, however, the effect would probably be enough worse that the picture could not be used without AGC circuits in receivers. Most present-day receivers have such circuits.

"The motion of the airplane will also have an effect on the ghosts which are received. The effect may be either a change in amplitude or a change in position of the ghost. Figs. 76-78 show the change in path difference as the plane moves around in a 20 mile diameter circle. It can be seen from these curves that for a majority of the ghosts, where the distance from the receiving antenna to the reflecting object is a fraction of a mile, the motion will be quite small. (1 microsecond delay time represents about 1.60 of the width of the picture.) Even when the ghosts move in the order of 20 microseconds, however, which is about as large as motion as is

likely to occur, it is believed that the slow rate at which the motion occurs will make the moving ghost no more objectionable than a stationary one. Figs. 67-70 show that the maximum amplitude of a ghost changes very little for changes in distance to the plane, but that the maximum amplitude may change appreciably for sidewise motion of the plane, which causes phase to vary. Even larger changes in amplitude, may be caused by the fact that a reflecting object may be oriented to give the maximum possible ghost signal for one position of the plane and be oriented wrong for a different position of the plane. This effect will be greater for high frequencies and large reflecting objects. In the UHF television band (475 to 890 m. c.), if a 3 ft. parabolic receiving antenna is used, any object large enough to produce a ghost will produce a sharp enough beam that the motion of the plane will cause a very substantial change in the amplitude of the ghost. Because of this, there is an appreciably greater chance of getting an objectionable ghost at some point in the plane's circle than would be the case with a fixed transmitting antenna at the same height. However, Fig. 74 shows that if a 3 ft. parabolic receiving antenna and a non-directional transmitting antenna need be only 1/40 to 1/100 the size of an object near the receiving antenna to cause an objectionable ghost. Because of this, it is felt that the greater number of objectionable ghosts which will occur due to objects near the receiving antenna for a STRATOVISION system, will be more than offset by the elimination of objectionable ghosts due to objects near the transmitting antenna, when the antenna is raised away from all nearby objects."

Many of these factors are brought up to date in the "Petition for Rule-Making submitted by Midwest Program on Airborne Television Instruction Inc.," and the accompanying "Engineering Exhibit - Petition for Rule-Making to Authorize the Use of Airborne Television Transmitters." Additional assumptions are made with respect to the potential and existing operational effects observed since operations under MPATI commenced in 1959.

The National Bureau of Standards has also undertaken calculations[12] and measurements[13] with respect to the MPATI program. The conclusions from the Decker study, although preliminary, indicate that the system will require the use of carefully designed equipment with maximum possible transmitter power and lowest possible receiver noise figures. Commercial UHF-TV receiving sets listed as currently available in the TASO report are probably not adequate for this system.

The conclusions of the NBS report suggest the possibility of atmospheric effects which may be pertinent in coverage analysis and standards considerations. Propagation anomalies which result from atmospheric refraction of radio waves have been observed in airborne propagation at 250-10,000 Mc/s.[14] The additional work being undertaken by NBS should be helpful infurther definition based upon the recordings program, but there is no conclusive data on this subject at this time, and continued airborne transmission would have to be considered experimental.

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[12] "Service Area of an Airborne Television Station," M. T. Decker, NBS Technical Note, No. 35, Boulder Laboratories, October, 1959.

[13] "National Bureau of Standards Measurement Program on UHF Airborne Television," R. S. Kirby, A. P. Barsis, and P. L. McQuate, NBS Report 7274, June 30, 1962. (Permission must be obtained from NBS to refer to this report.)

[14] "Refraction Anomalies in Airborne Propagation," Mong S. Wong, Proceedings of the IRE, pp. 1628-1638, September, 1958.

THE IMPACT OF MPATI AIRBORNE TRANSMISSION ON LAND-BASED UHF BROADCAST TELEVISION FACILITIES

Determination of Standards for Evaluation

The airborne operations proposed by the MPATI will cause interference to ground-based stations; until now, what has not been known is the nature and extent of this interference. Co-channel and adjacent channel interference is acknowledged by the MPATI, but, in addition, certain other interference possibilities, such as those arising from operation on "image" frequencies, must be considered.

The range within which ground stations would be affected by the various types of interference depends upon assumptions regarding propagation and desired-to-undesired signal ratios. These factors will be discussed below. In addition, once the tools for calculating interference are at hand, it is necessary to decide what degree of interference, if any, is permissible; and this, in turn, requires a decision as to the facilities with which it is assumed a ground station will operate.

To take the latter factor first, it seems reasonable to assume land-based operations with an effective radiated power of 500 kilowatts and an average effective antenna height of 1,000 feet. This level of effective radiated power can be obtained with an antenna having a power gain of approximately 25 and a 25-kilowatt transmitter.

The 25-gain antenna provides a desirable concentration of the radiated signal without compressing the beam-width below acceptable limits. The 25-kilowatt transmitter, at the present time and for the foreseeable future, appears to be the upper limit of that which is economically feasible and is practical in a community of average size.

This same rationale is equally applicable to an effective antenna height of 1,000 feet. Throughout much of the area which would be affected by the proposed MPATI operation, the effective antenna height would not differ materially from the height of the supporting tower. Aside from economic factors, consideration also must be given to potential aeronautical hazard problems, which would undoubtedly arise if structures appreciably taller than 1,000 feet were to be considered standard antenna height.

With regard to the question of the extent to which interference is tolerable, it may be observed that two ground stations operating on the same channel with the facilities assumed above will cause interference to each other when they are located 155 miles apart. (This statement anticipates assumptions regarding propagation and desired-to-undesired signal ratios which are discussed below.) It would seem reasonable to permit an airborne station to cause interference to a ground station in approximately the same degree.

Accordingly, the following studies are predicated on the assumption that this degree of interference is permissible.

Propagation Curves

The propagation curves for Channels 14 through 83 which are contained in the FCC Rules are not appropriate for use in predicting service and interference from an airborne operation. The MPATI has developed curves which it proposes for use in making these determinations; in addition, it has curves for ground stations which are suggested for use in evaluating the effects of airborne transmission. The latter curves, when compared to those in the FCC Rules, show a significantly different distribution of field strength within the service area of a UHF station (bounded by the 64 db contour) and an increase in the service radius.

It is not known whether the propagation curves proposed by the MPATI provide a sound basis for estimating the impact of airborne operation on ground stations. The curves are based on theoretical considerations, and, from this standpoint, they represent a reasonable estimate of the propagation characteristics to be expected. It must be emphasized, however, that only a very limited amount of measured data is available which could serve to substantiate these curves. Thus, while they have been used to estimate the interference caused by the proposed airborne operation to ground stations, it should be understood that this assessment can by no means be regarded as definitive.

The curves proposed by the MPATI for ground stations are found by NAEB engineers to exhibit characteristics with regard to the extent of service area and the magnitude of signals available within the service area which have not yet been proved by field measurements. It is held that a more realistic estimate of these factors is provided by the curves in the FCC Rules. It might be noted that experience with field strength surveys tends to show that in certain circumstances even the latter curves are somewhat optimistic.

In calculating the interference between ground-based stations, use was made of the F(50, 10) curves which are presented in the FCC Technical Research Report 2.4.16.

The television rules of the FCC recognize a number of types of interference between UHF stations and precautions are taken through mileage separations to avoid or minimize such interference. The requirements of the Rules are summarized in the following table:

Table 1

FCC MILEAGE SEPARATION RULES FOR
LAND-BASED UHF BROADCAST STATIONS

TYPE OF INTERFERENCE	CHANNEL SEPARATION	REQUIRED MINIMUM MILEAGE SEPARATION
Co-channel	0	155 miles 1/
Adjacent Channel	± 1	55
Intermodulation	± 2,3,4,5	20
Oscillator Radiation	± 7	60
I. F. Beat	± 7,8	20
Sound Image	± 14	60
Picture Image	± 15	75

1/ Zone 1

Co-Channel Interference

The MPATI has proposed that a separation of 290 miles be required between the proposed airborne operations and ground stations operating on the same channels. The MPATI assumption is that ground stations would operate with an effective radiated power of 1000 kilowatts and an effective antenna height of 2,000 feet, thereby providing a stronger signal less subject to airborne interference. The 290-mile separation which they propose, therefore, would produce interference equivalent to that which would be permitted by one such ground

station to another. The calculations which underlie this proposal were made using the propagation curves which are recommended in the MPATI petition to the FCC.

NAEB calculations, based on the different assumptions and propagation curves concerning transmitter power and antenna height previously discussed, indicate that the co-channel separation between airborne and land-based stations should be increased to 320 miles if the interference is to be held to a level equivalent to that which would be caused by a ground station. Here, as in the case of the MPATI calculations, the interference determinations are actually made from a point 10 miles closer to the assumed ground station so as to take into account the orbital excursions of the aircraft.

In both cases, a desired-to-undesired signal ratio of 28 db has been used. This ratio is generally accepted as being valid for offset carrier operation. It might be noted that a ratio of 45 db is required when the carriers are not offset. While it should not be difficult to provide for offset carrier operation in the case of those stations located just beyond the minimum co-channel separation, some assignments in the next ring would probably operate with the same carrier frequency assignment as the airborne operation. It is quite likely that interference problems could arise out of

this situation. The propagation data available do not provide an adequate basis for a definite judgment in this regard.

Adjacent Channel Interference

The MPATI suggests that the adjacent channel separation requirement be set at 200 miles. Our studies indicate that this separation would probably be adequate. There is no generally accepted desired-to-undesired signal ratio for the determination of adjacent channel interference; if, however, a ratio of approximately -10 db were to be assumed, the 200-mile separation would provide protection equivalent to that obtained with a 320-mile co-channel separation.

Intermodulation, Oscillator Radiation and I. F. Beat Interference

It is believed that, as the MPATI suggests, these potential sources of interference could be eliminated from consideration insofar as an airborne system is concerned. It must be emphasized, however, that the elimination of oscillator radiation interferences rests on the assumption that airborne transmissions would be received only in schools or other places with specially-equipped receivers. The assumption is a workable one, but elimination of this type of interference is not consistent with

effective reception of an airborne signal under normal circumstances. Granting of this assumption reemphasizes the point-to-point nature of the airborne signal, and curtails any kind of general home reception of MPATI in most areas.

Picture and Sound Image Interference

The MPATI states that these sources of interference may also be eliminated from consideration. The FCC, however, in its notice of rule-making in this proceeding, indicated that some degree of protection would be necessary if the normal service area of a ground station is to remain unimpaired.

There is a wide divergence of views regarding the desired-to-undesired signal ratio or ratios which should be used to calculate this type of interference. The MPATI suggests ratios of -4 db and -20 db for the determination of picture and sound image interference respectively. The Commission states that a ratio of 0 db or 10 db is necessary to avoid picture image interference. It states further that in the case of sound image interference protection for color reception would require about the same separation as would be required for picture image protection.

The NAEB study of the impact of airborne transmission has been conducted using the ratio of -4 db suggested by the MPATI. It was found that a separation of 260 miles would be required if picture and sound image interference is to be held to the equivalent of that which would be tolerated from a co-channel operation.

Impact of the MPATI Proposal on the FCC and NAEB Assignment Plans

The expansion of the MPATI's airborne transmission will cause interference to land-based stations. If this interference is based on new standards which the MPATI suggests are more appropriate and realistic, the number of existing stations and proposed assignments which will be affected is considerably less than when the interference is based on standards and curves used by the FCC. The NAEB has studied the impact of airborne interference using these two different standards on its own proposed UHF Table of Assignments. It has been possible to indicate the specific assignments which would be deleted as well as a small number of communities to which other channels could be assigned. The FCC has conducted a similar study of its own proposed plan, and has indicated its findings in its Notice of Proposed Rule-Making, in Docket 15201, October 24, 1963.

Impact of MPATI Proposal on the Proposed FCC Plan

> "If we accept the MPATI assumption that we need to be concerned only with co-channel and adjacent channel separations, 15 of the assignments proposed in the new UHF Table would not meet the proposed 290-mile co-channel separation and 17 would fail to meet the proposed 200-mile adjacent channel separation requirement. We have proposed the reservation of eight of these channels for educational use. In

addition, 4 assignments which Canada has recently assigned in the Province of Ontario fall short of the required co-channel separation."15/

With respect to picture and sound image interference, the FCC Notice has pointed out:

"Since the MPATI receivers will be operating in the upper end of the UHF television band, receivers tuned to their signals will not be exposed to potential 'image' interference due to the operation of the MPATI transmitters. Such interference is most likely to occur in the weaker signal areas of the ground-based television stations which are located within or near the service area of the airborne stations. If interference is to be avoided, the signal from an airborne station operating on the fifteenth channel above the one to which a television receiver is tuned cannot exceed a level equal to, or in some cases 10 decibels weaker than the desired signal. In order to protect the normal service area of a ground-based television station operating with ½ megawatt of power from an antenna 1,000 feet above average terrain, the airborne station flying at 23,000 feet and radiating 100 kilowatts would have to be about 200 miles away. While somewhat shorter separation could be tolerated with respect to the sound image (fourteenth channel above the desired channel) for monochrome reception, protection for color reception would require about the same separation as the picture image protection.

"If the above assumptions are correct, ground-based television stations would not be operated within the service area of the airborne stations without having impaired coverage due to 'image' interference. This would require deletion of assignments in 30 additional places proposed in the new Table, or, if assignments were made in spite of the 'image' interference problem, 30 stations would suffer impaired coverage due to interference."16/

15/ Specific assignments which are affected are listed in the appendix of the FCC's Notice of Proposed Rule-Making, Docket No. 15201, October 24, 1963.

16/ Specific assignments which are affected are listed in the appendix of the FCC's Notice of Proposed Rule-Making, Docket No. 14201, October 24, 1963.

The FCC also referred to the general problem of UHF translators in the MPATI area and nearby:

> "Also to be considered is the possible impact of the proposal on the UHF translator service, wherein stations operate on Channels 70 and above. The Midwest states which MPATI proposed to serve are not the portion of the nation where this service is most used; but within these six states there are at least two translators authorized within 290 miles of Montpelier, Indiana, on channels MPATI seeks, and another on an adjacent channel within 200 miles. Two additional translators are authorized in western Pennsylvania on channels MPATI would use, within the 290-mile radius. With respect to these, and other translators which may be authorized within this area, obviously interference considerations might exist. Furthermore, the Commission indicated in the initial Notice in Docket No. 14429 that we anticipated that UHF translators would be used to provide more uniform coverage by UHF stations. The efforts which we are making to foster the expanded use of the UHF channels could be hampered if prospective UHF broadcasters in the MPATI area were precluded from using UHF translators."

Impact of the MPATI Proposal on the Proposed NAEB UHF Assignment Plan

The NAEB has conducted two studies designed to use the computer program which was devised to develop the UHF assignment table which the NAEB submitted to the FCC in November, 1963.[17/]

17/ NAEB, UHF TELEVISION ASSIGNMENT PLAN, Washington, D.C., 1963.

The speed of the computer and accessibility of appropriate data in the computer program made it practical to determine the impact of the proposed MPATI expansion in two different contexts. One was by using new standards which MPATI recommends for calculating interference and determining UHF propagation characteristics, and the second by using standards developed by NAEB engineers.

First, the computer was programed to print out the location and channel number of assignments which would have to be deleted if MPATI propagation curves were adopted. These data are listed in Table 2. New assignments which could be added to the Table of Allocations to replace those which had to be deleted are noted in Table 3.

Table 2

ASSIGNMENTS IN THE NAEB UHF ASSIGNMENT TABLE WHICH MUST BE DELETED BECAUSE OF INTERFERENCE FROM MPATI TRANSMISSION (BASED ON MPATI INTERFERENCE STANDARDS)[18/]

	Channel	City
1.	76	Alton, Illinois
2.	78	Belleville, Illinois
3.	73	Decatur, Illinois
4.	74	Joliet, Illinois
5.	71	Matton, Illinois
6.	72	Monmouth, Illinois
7.	83	Normal, Illinois
8.	79	Ottowa, Illinois
9.	75	Rantoul, Illinois
10.	80	Rockford, Illinois

18/ 290 Mile-channel separation and 200 mile adjacent channel separation. No allowance for picture and sound image interference.

Table 2 (cont'd)

	Channel	City
11.	82	Springfield, Illinois
12.	76	Waukegan, Illinois
13.	80	Anderson, Indiana
14.	82	Columbus, Indiana
15.	80	Evansville, Indiana
16.	82	Hammond, Indiana
17.	76	Hartford City, Indiana
18.	77	Indianapolis, Indiana
19.	78	Logansport, Indiana
20.	81	Terre Haute, Indiana
21.	72	Washington, Indiana
22.	78	Cynthiana, Kentucky
23.	81	Frankfort, Kentucky
24.	83	Louisville, Kentucky
25.	73	Louisville, Kentucky
26.	72	Maysville, Kentucky
27.	76	Middlesboro, Kentucky
28.	83	Benton Harbor, Michigan
29.	77	Benton Harbor, Michigan
30.	76	Detroit, Michigan
31.	73	Flint, Michigan
32.	75	Grand Rapids, Michigan
33.	72	Kalamazoo, Michigan
34.	79	Owosso, Michigan
35.	76	Athens, Ohio
36.	75	Bellefontaine, Ohio
37.	77	Coshocton, Ohio
38.	81	Fostoria, Ohio
39.	71	Greenville, Ohio
40.	83	Marion, Ohio
41.	80	Newark, Ohio
42.	78	Sandusky, Ohio
43.	79	Springfield, Ohio
44.	78	Clarksburg, West Virginia
45.	72	Fairmont, West Virginia
46.	72	Madison, Wisconsin
47.	74	Chatham (Canada)
48.	80	Chatham (Canada)
49.	82	Lexington (Canada)
50.	72	Sarnia (Canada)

REPLACEMENT ASSIGNMENTS FOR ASSIGNMENTS
DELETED BECAUSE OF INTERFERENCE FROM
MPATT BASED ON MPATT INTERFERENCE STANDARDS

Channel 83 Assigned to Alton, Illinois
Channel 79 Assigned to Belleville, Illinois
Channel 81 Assigned to Evansville, Indiana
Channel 77 Assigned to Clarksburg, West Virginia

Next, using standards which the NAEB considers to be appropriate, the computer was programed to calculate which assignments in the proposed NAEB UHF Assignment Table would be deleted because of interference from MPATT Airborne transmission. These assignments and their locations are listed in Table 4. The assignments which could be added to the NAEB Table of Allocations to replace those which had to be deleted are listed in Table 5.

Table 4

ASSIGNMENTS IN THE NAEB UHF ASSIGNMENT TABLE
DELETED BECAUSE OF INTERFERENCE
FROM MPATT TRANSMISSION
(BASED ON NAEB INTERFERENCE STANDARDS)[19/]

	Channel	City
1.	76	Alton, Illinois
2.	78	Belleville, Illinois
3.	62	Bloomington, Illinois
4.	57	Centralia, Illinois
5.	65	Champaign-Urbana, Illinois

19/ 300 mile co-channel separation and 200 mile adjacent channel separation picture and sound image interference requiring 260 mile separation.

Table 4 (cont'd)

	Channel	City
6.	73	Decatur, Illinois
7.	74	DeKalb, Illinois
8.	75	Dixon, Illinois
9.	76	Joliet, Illinois
10.	77	Mattoon, Illinois
11.	78	Monmouth, Illinois
12.	79	Newton, Illinois
13.	80	Normal, Illinois
14.	81	Ottawa, Illinois
15.	82	Pontoni, Illinois
16.	83	Rockford, Illinois
17.	84	Springfield, Illinois
18.	85	Springfield, Illinois
19.	86	Waukegan, Illinois
20.	87	Anderson, Indiana
21.	88	Columbus, Indiana
22.	89	Evansville, Indiana
23.	90	Fort Wayne-Homecke, Indiana
24.	91	Frankfort, Indiana
25.	92	Gary, Indiana
26.	93	Hammond, Indiana
27.	94	Hartford City, Indiana
28.	95	Indianapolis, Indiana
29.	96	Indianapolis, Indiana
30.	97	Logansport, Indiana
31.	98	Madison, Indiana
32.	99	Peru, Indiana
33.	100	South Bend, Indiana
34.	101	Terre Haute, Indiana
35.	102	Terre Haute, Indiana
36.	103	Washington, Indiana
37.	104	Cynthiana, Kentucky
38.	105	Elizabethtown, Kentucky
39.	106	Frankfort, Kentucky
40.	107	Glasgow, Kentucky
41.	108	Lexington, Kentucky
42.	109	Louisville, Kentucky
43.	110	Louisville, Kentucky
44.	111	Louisville, Kentucky
45.	112	Maysville, Kentucky
46.	113	Middlesboro, Kentucky

Table 4 (cont'd)

	Channel	City
47.	69	Pikeville, Kentucky
48.	70	Ann Arbor, Michigan
49.	71	Benton Harbor, Michigan
50.	72	Benton Harbor, Michigan
51.	73	Detroit, Michigan
52.	74	Flint, Michigan
53.	75	Grand Rapids, Michigan
54.	76	Grand Rapids, Michigan
55.	77	Kalamazoo, Michigan
56.	78	Manistee, Michigan
57.	79	Midland, Michigan
58.	80	Owosso, Michigan
59.	81	Saginaw, Michigan
60.	82	Athens, Ohio
61.	83	Bellefontaine, Ohio
62.	84	Bowling Green, Ohio
63.	85	Canton, Ohio
64.	86	Chillicothe, Ohio
65.	87	Cincinnati, Ohio
66.	88	Coshocton, Ohio
67.	89	Defiance, Ohio
68.	90	Fostoria, Ohio
69.	91	Greenville, Ohio
70.	92	Lima, Ohio
71.	93	Lorain, Ohio
72.	94	Marietta, Ohio
73.	95	Marion, Ohio
74.	96	Newark, Ohio
75.	97	Sandusky, Ohio
76.	98	Springfield, Ohio
77.	99	Springfield, Ohio
78.	100	Tiffin, Ohio
79.	101	Warren, Ohio
80.	102	Zanesville, Ohio
81.	103	Indiana, Pennsylvania
82.	104	Cookeville, Tennessee
83.	105	Charleston, West Virginia
84.	106	Clarksburg, West Virginia
85.	107	Fairmont, West Virginia
86.	108	Huntington, West Virginia
87.	109	Janesville, Wisconsin

Table 4 (cont'd)

	Channel	City
88.	64	Kenosha, Wisconsin
89.	72	Madison, Wisconsin
90.	59	Milwaukee, Wisconsin
91.	68	Sheboygan, Wisconsin
92.	74	Chatham (Canada)
93.	80	Chatham (Canada)
94.	82	Leamington (Canada)
95.	72	Sarnia (Canada)

Table 5

REPLACEMENT ASSIGNMENTS FOR ASSIGNMENTS
DELETED BECAUSE OF INTERFERENCE FROM
MVDDT BASED ON RAND STANDARDS

Channel 82 Assigned to Alton, Illinois
Channel 79 Assigned to Belleville, Illinois
Channel 71 Assigned to Centralia, Illinois
Channel 73 Assigned to DeKalb, Illinois
Channel 81 Assigned to Evansville, Indiana
Channel 73 Assigned to Glasgow, Kentucky
Channel 73 Assigned to Manistee, Michigan
Channel 79 Assigned to Midland, Michigan
Channel 77 Assigned to Canton, Ohio
Channel 77 Assigned to Charleston, West Virginia
Channel 79 Assigned to Huntington, West Virginia
Channel 73 Assigned to Milwaukee, Wisconsin

Summary of the Impact of MVDDT Airborne Transmission
on Land-Based UHF Broadcast Television Stations

To a large extent, Tables 2-5 tell their own story. If the MVDDT proposal for expansion were approved, and six airborne channels on 72, 74, 76, 78, 80 and 82 were authorized to operate on a regular basis,

62 channel assignments in the FCC's proposed plan would need to be deleted or would operate with interference brought about by the airborne operation. In the proposed HAEB plan, 83 assignments would be affected. Even using the standards which are proposed by NPAEI the use of these six airborne channels would require the deletion of at least 46 proposed assignments.

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The NAEB has studied the impact of airborne transmission proposed by the NWRTI on two different land-based UHF assignment plans. The study indicated that no less than 60 channels in the FCC plan would be affected by such an operation, and 83 channels in the NAEB plan would be involved. Using new standards proposed by the NWRTI, as many as 46 proposed assignments would need to be deleted.